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ABSTRACT

A study was made to investigate the hypothesis that the ability to determine, on a map, where one is located and in which direction one is headed, requires an understanding of the ways in which views change from different locations and orientations. Approximately 200 kindergarten through second-grade children were first tested individually for their understanding of projective spatial concepts. Children were given a perspective-taking task in which colored disks and cylinders replaced the traditional papier-mache mountains, and were asked which of six photographs had been taken from specified locations around the array. Additionally, children were shown a series of locations on a model of a landscape and were asked to reproduce those locations on an identical model, once when the two models were in spatial alignment and once when the child's model had been rotated by 180 degrees. With an exception or two, results showed the anticipated patterns of lower performance for unaligned rather than aligned conditions. Children were later given a variety of mapping tasks as part of their regular classroom instruction. Data from the directional mapping tasks were consistent with predictions based on Piagetian theory. (RH)

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Perspective-Taking in Piagetian and Pennsylvanian Landscapes[1]

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The research described in the present paper is a small piece of a much larger program of research developed to study mapping in relation to a range of variables drawn from developmental and cartographic theories. Elsewhere (Downs & Liben, in press) we have reported data bearing upon preoperational children's abilities to interpret maps and aerial photographs. Consistent with the Piagetian view that children's understanding of the arbitrary nature of symbols is not yet fully developed in the preoperational period, we have found that preschoolers show serious confusions in interpreting referents of maps and aerial photographs. Some three- and four-year-old children, for example, assert that a road shown in red on a map will "actually be red if you drive on it" or that an airplane stands for a particular airplane, and should that airplane fly away, there would no longer be an airplane on the map.

Here we report data bearing on the hypothesis that some significant aspects of children's abilities to use maps rest upon their mastery of projective spatial concepts as conceptualized within Piagetian theory (Piaget & Inhelder, 1956). More specifically, we hypothesized that the ability to determine, on a map, where one is located and which direction

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one is headed, requires an understanding of the ways in which views change from different locations and orientations. This understanding depends upon a complex set of alignments among self, map, and referent space.

To examine the hypothesized relationship between projective concepts and mapping, approximately 200 kindergarten through second-grade children were first tested individually for their understanding of projective spatial concepts. Children were given a perspective-taking task in which colored disks and cylinders replaced the traditional papier-mache mountains, and were asked which of six photographs had been taken from specified locations around the array (see Figure 1).

Given that earlier work has shown that some children have difficulty selecting representations of their own view (Liben, 1978), the number correct was tallied separately for questions in which the camera view matched the child's own view ("self" view) and those in which the camera view differed from the child's view ("other" view). Data showed that although there were expected age-linked increases in performance, both tasks elicited generally low levels of performance. This finding may rest on the fact that even on the self view, an understanding of projective spatial concepts is relevant insofar as the circles become ellipses, and the more distant circles become smaller. Also noteworthy was the large range of individual differences observed in performance even within any single grade.

The second Piagetian projective task was based on the landscape task described by Piaget and Inhelder (1956, Chapter 14) and subsequently modified by Laurendeau and Pinard (1970). Children were shown a series of locations on one model of a landscape (see Figure 2), and asked to reproduce those locations on an identical model, once when the two models

were in spatial alignment, and once when the child's model had been rotated by 180°. The landscape used in the present research was fully symmetrical with respect to the sections formed by the railroad and road. Furthermore, one pair of matching quadrants contained no internal features whatsoever, thus making locations in these areas totally confusable except on the basis of recognizing projective viewpoint.

Percentages of correct responses are given, by grade and position, in Figure 3. With an exception or two, results showed the anticipated patterns of lower performance for unaligned than aligned conditions; for locations on landmarks that were not unique (e.g., two identical lakes) than for items that were unique (e.g., the only pink house); and for younger than older children, although again, individual differences within grades were striking.

Children were later given a variety of mapping tasks as part of their regular classroom instruction. Among the tasks hypothesized to draw on projective spatial concepts were those in which children were given colored arrow stickers and asked to put them on two-dimensional representations to indicate directional information. In one of these tasks, children were given a map of their classroom while an adult stood at a series of predetermined locations, arm outstretched, pointing straight ahead. Children were asked to put the colored arrow sticker on the map "to show where Mr. Downs is standing and which way he is pointing." The task was given under two conditions, once when the child's map was aligned with the surrounding classroom, and once when the map was rotated 180°.

The child's placement of each arrow was measured, to the nearest degree, with respect to the entrance-door base wall, and then grouped into one of eight 45°-segments of a circle, bracketed around the correct

response. Thus, for example, for the 0^{o} orientation, responses falling between 338^{o} and 360^{o} or between 0^{o} and 22^{o} were categorized as correct. As an example, data on correct responses from a single classroom are presented in Figure 4.

Collapsing over subjects and items, performance on the person-direction task in the aligned condition was relatively good, with correct responses averaging 63%, 75%, and 87% by grade, respectively. While group data show performance increasing overall with grade, considerable variability within grade was evident as well.

Performance on the person-direction task under the unaligned condition was far lower. The percentages correct, averaged across subjects and items, were 22%, 53%, and 67% by grade, respectively. Again, in addition to an increase in performance across age at the group level, large variability within grade was evident.

Performance also varied as a function of item orientation. Figure 5 presents the percentages of responses falling into each of the 8-segment (45^{o}) categories, separately by grade, for the aligned condition. As predicted, percentages of correct responses (shown in the heavily-outlined directional segments on the figure) tended to be higher in the 0^{o} and 180^{o} orientations than in the other orientations, with the difference decreasing across grades. Errors in the aligned condition generally tend to fall into segments near the correct response.

Comparable data for the unaligned condition are shown in Figure 6. In addition to revealing far lower percentages of correct responding, these data show that in most cases, errors in the unaligned condition generally tend to fall into the inverse segment, that is, at angles opposite to the correct response. Errors of this kind are, of course, readily understood

as the result of the child's failure to appreciate the reversed relationship between the actual space and the map.

In a second direction task, children were asked to place arrows on a map of the school neighborhood to show the directions from which aerial photographs of the school had been taken. First, the general concept of aerial views was introduced by a discussion of a bird's eye view of the school and of a drawn plan view. Each child was given a copy of a black and white aerial photograph of the school (Figure 7) and a school map (Figure 8). After some general discussion of the relationship between aerial photographs and maps, children were given colored arrow stickers and asked to put the first one on the school map to show which way the camera had been facing when the photograph had been taken. Seven additional aerial photographs of the school were then projected.

As each slide was shown, children tried to find the school in a game-like fashion. The location of the school was then confirmed by one of the experimenters pointing to its location on the screen. Once the school had been located on the slide and all the children could point to it, children were asked to place a designated colored arrow sticker on the school map to indicate which direction the camera had been pointing when the photograph was taken.

As in the person-direction tasks given in the classroom, each arrow response was scored to the nearest degree, and then categorized into one of eight 45°-segments. Data were also scored with a more lenient categorization system (90° segments) because the determination of the correct response was less precise than in the person-direction tasks, but patterns of findings remain comparable.

Using the 45° criterion, performance was extremely low, with the percentages correct (averaging across subjects and items) only 16% and 15% for first- and second-grade respectively. Distributions of total scores confirm the low levels of performance, and unlike most of the other mapping tasks included in this project, show not a single child performing perfectly or nearly perfectly even with the more lenient scoring system. A number of children do, however, appear to have understood the general concept, as shown by responding correctly to about half the items.

Performance on the aerial-direction task by individual item is shown in Figure 9 separately by grade for the 45°-segment scoring system. The particular combination of inter-item variations suggest several factors that may help to account for task difficulty, including scale and range of the photographs, and experience with particular photos.

In the third direction task, children were shown a series of nine slides (randomly ordered for each class) that showed computer-generated perspective representations of the local topography such as the one shown in Figure 10. For each view, children were asked to place an arrow on a contour map (see Figure 11) of the same region to show the direction from which the area was viewed in the representation. Seven of the nine representations were at a 30° viewing angle, with azimuths of 45°, 90°, 135°, 180°, 225°, 270°, and 315°. Two additional representations were at a 45° viewing angle, at azimuths of 270° and 315°. As in the other direction tasks, the orientations of children's arrows were measured to the nearest degree, and categorized into 45° segments.

Performance on the perspective-view task was again low, although not as uniformly so as on the aerial-direction task. Averaging over individuals and items, correct responses were given by 21% and 22% of

first- and second-graders respectively. While scores are predominately low, it is noteworthy that perfect performance (9 correct) was obtained by one first-grade subject, and nearly perfect performance (8 correct) was obtained by one second-grade subject.

As in other tasks, differences among items were evident. Responses in each 45° segment are given, by grade, for each of the seven 30° viewing angle representations in Figures 12 and 13. (Parallel response patterns were found on the two 45° viewing angle items and thus are omitted to reduce graphic clutter.)

The most striking variation among items is that performance was better on items for which the correct response was at a corner of the map (i.e., the 45°, 135°, 235°, and 315° perspective views) than on items for which the correct response was at the side of the map (i.e., the 90°, 180°, 270° views). Interestingly, while the first-graders' errors on side views are dispersed relatively evenly across the 45°-segments, the second-graders' errors on these side items tend to fall at angles bracketing the correct response.

One possible explanation of this pattern of results is that some of the second graders have begun to appreciate (although have not yet mastered) one aspect of perspective evident in the computer-generated drawings, that is, that there is line convergence with perspective depth. In the corner views, they take advantage of the aiming point available on both the perspective view and the map itself, hence correctly selecting a corner on the contour map. In the side views, they are unable to coordinate the pair of vanishing lines to find the correct angle. That is, they do not recognize that the correct angle would be orthogonal to the side, found by bisecting the angle formed by the two receding parallel

sides of the perspective view. Instead, they attend only to one vanishing line or the other, attempting to reproduce the angle of that single line on the contour map. Further evaluation of this interpretation would be possible by coding the location of arrows. If the interpretation offered is correct, second-graders' arrows should be at the correct side of the contour map, even though the arrows are not angled correctly. (Data relevant to this implication have not yet been examined.)

In summary, at the group level of analysis, the data from the directional mapping tasks are consistent with predictions based on Piagetian theory. That is, if--as Piaget and Inhelder (1956) argued--the early elementary school period is a time in which children are only beginning to develop an understanding of projective spatial concepts, children would be expected to have difficulty on mapping tasks in which there is a lack of alignment between the self and representation (as in the unaligned condition of the classroom direction tasks), or in which it is necessary to determine how scenes look from different perspectives (as in the directional tasks using the school aerial photographs and the computer-generated perspective views).

We have only recently begun to examine the evidence for the more powerful claim that children's performance on the Piagetian spatial tasks is correlated with mapping performance, even after effects of chronological age, general intellectual (verbal) achievement and spatial abilities have been partialled out. Preliminary analyses suggest that this is the case, although not necessarily with a quantitatively strong relationship and not for every mapping skill tested.

While this presentation has focused on only a small piece of our work, we believe that--apart from the specific data reported--it provides support

for our more general contention that developmental and cartographic theories can be successfully integrated to examine the development of graphic representation, and to suggest ways in which a richer understanding of spatial representation may be promoted through a range of classroom activities.

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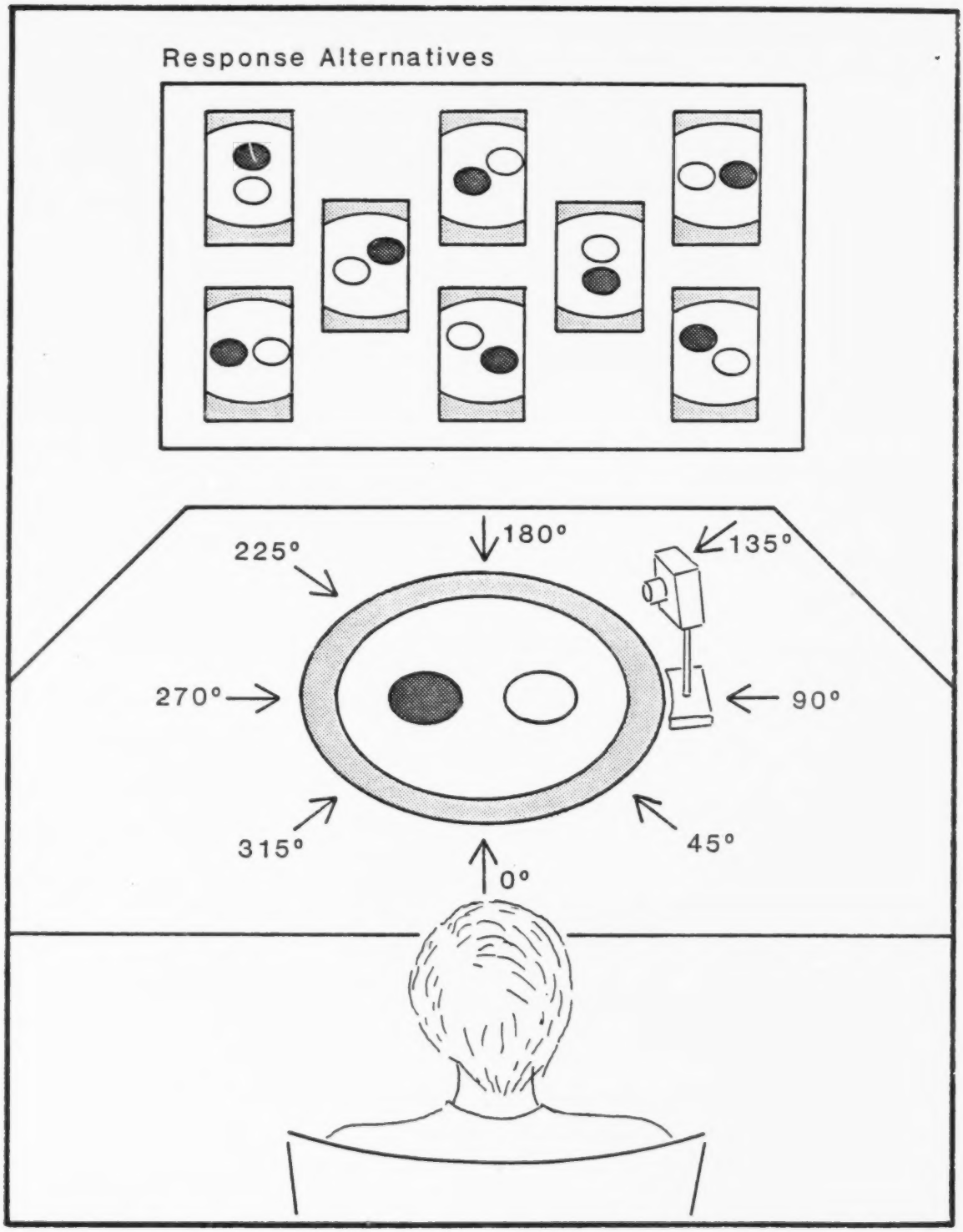


Figure 1. Modified Perspective-taking Task

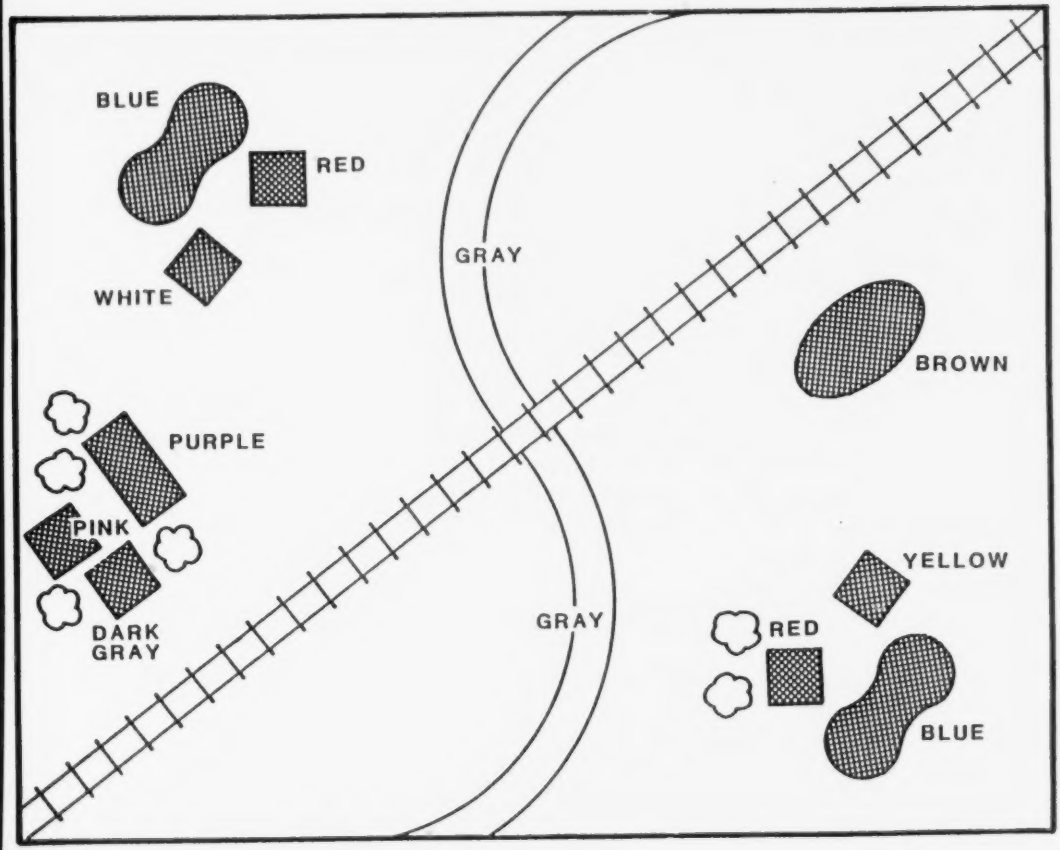


Figure 2. Diagram of the Landscape Task

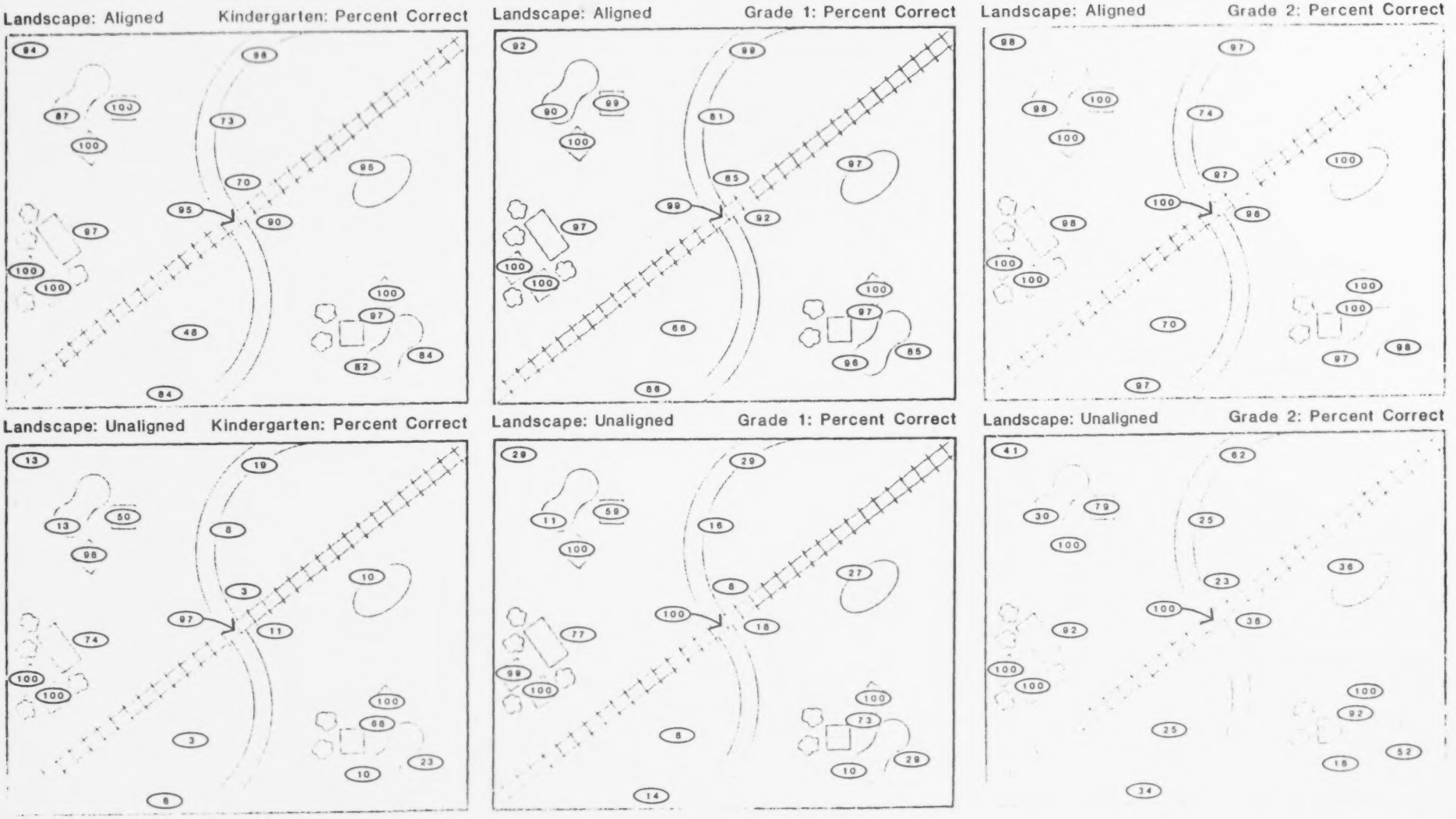


Figure 3. Landscape Task, Percentage Correct by Location, Condition (Aligned, Unaligned) and Grade

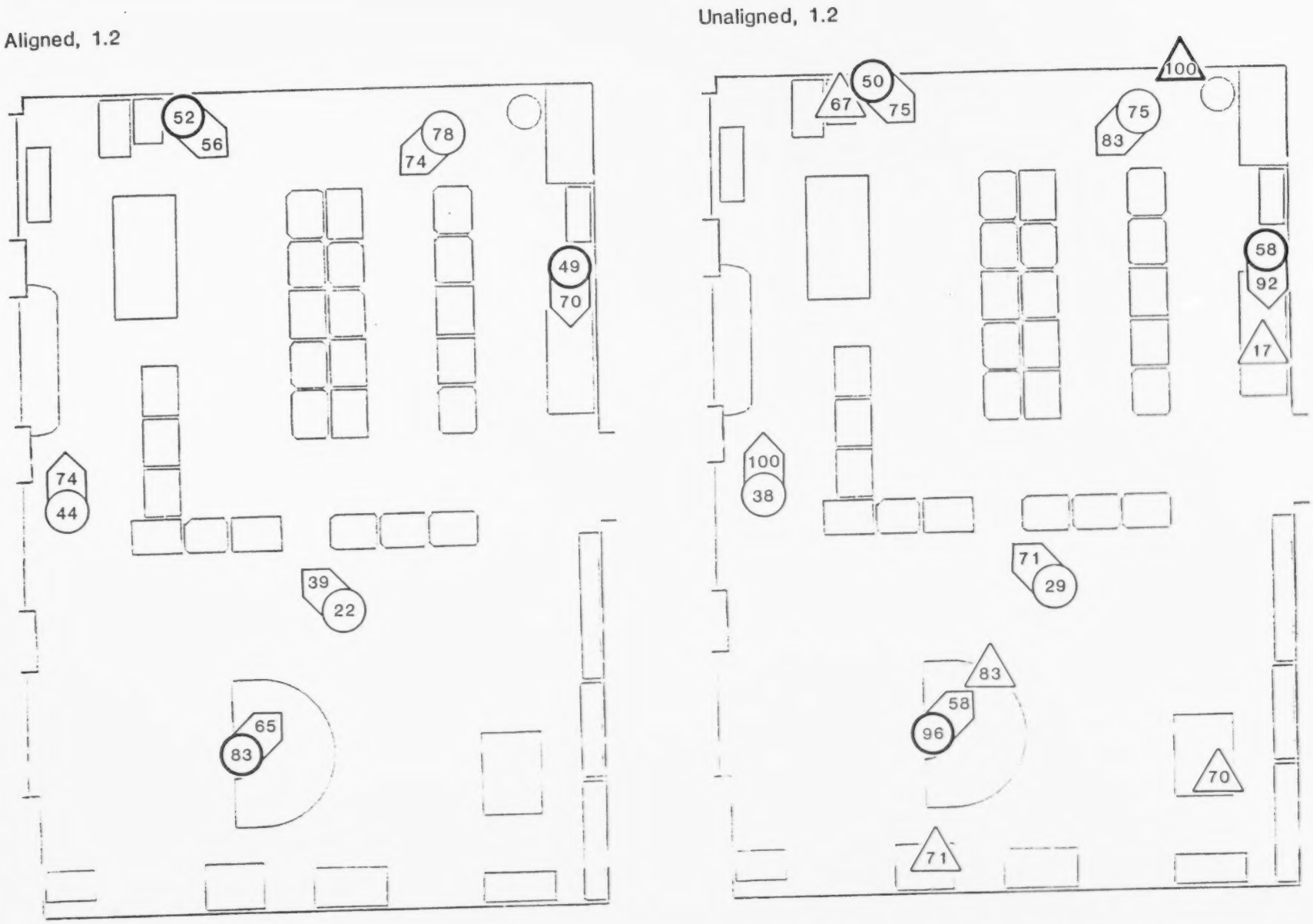


Figure 4. Sample Classroom Map Showing Percentage Correct Arrow Directions in Person-Direction Task under Aligned and Unaligned Conditions (Numbers shown in circles and triangles refer to additional tasks not discussed in text.)

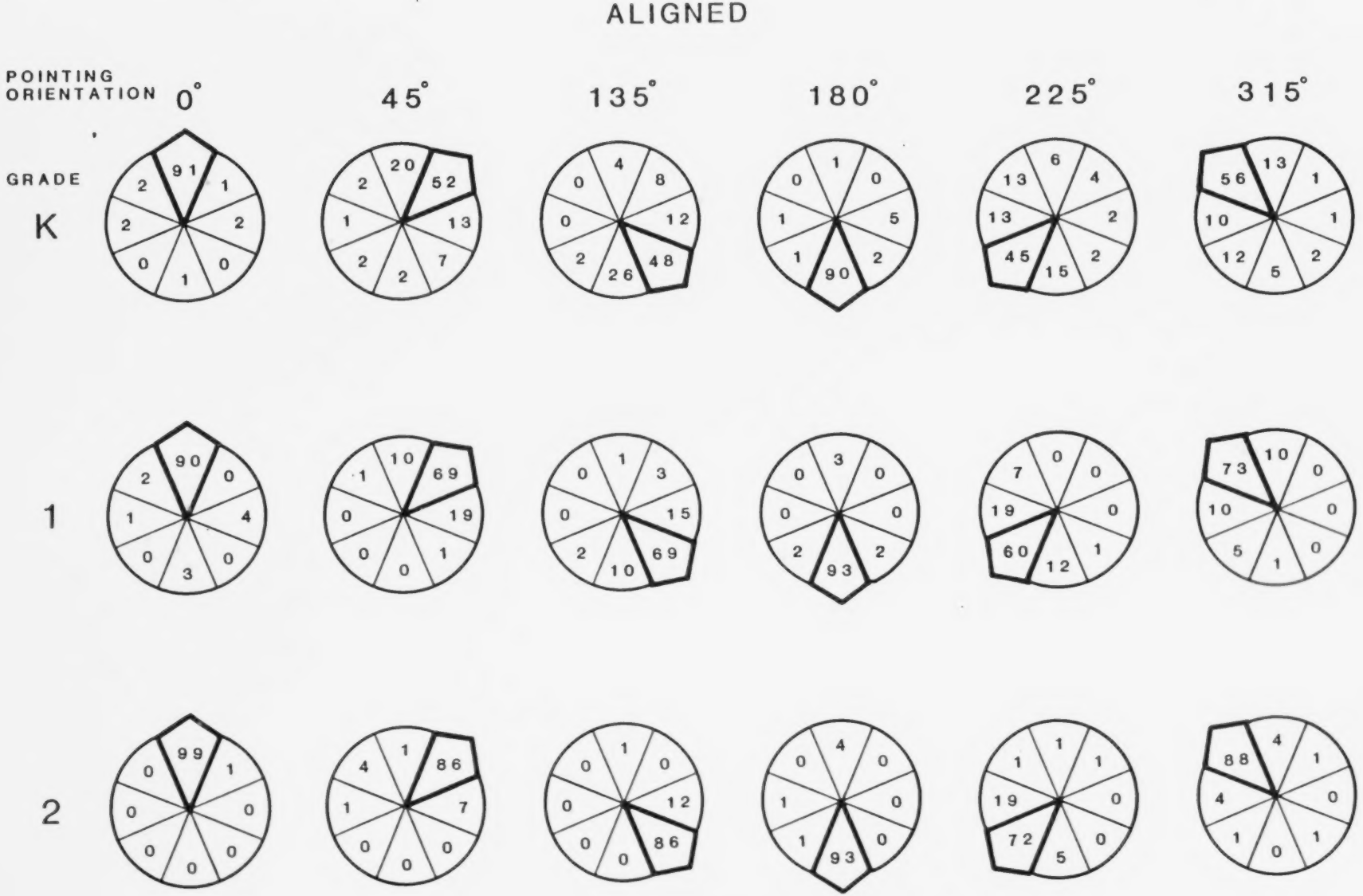


Figure 5. Person Direction Task, Percentage Distribution of Angular Responses by Item Orientation and Grade, Aligned

UNALIGNED

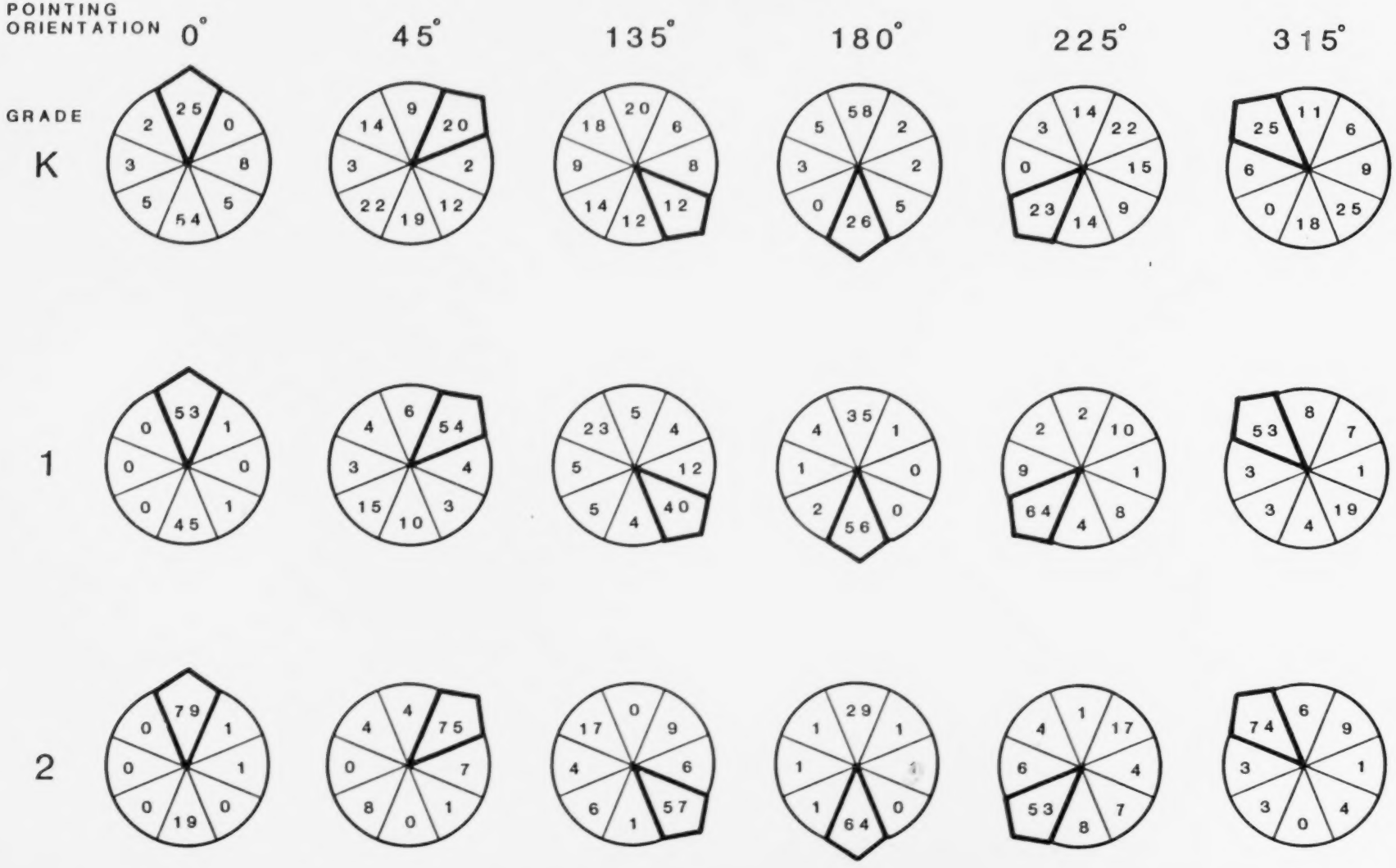


Figure 6. Person Direction Task, Percentage Distribution of Angular Responses by Item Orientation and Grade, Unaligned

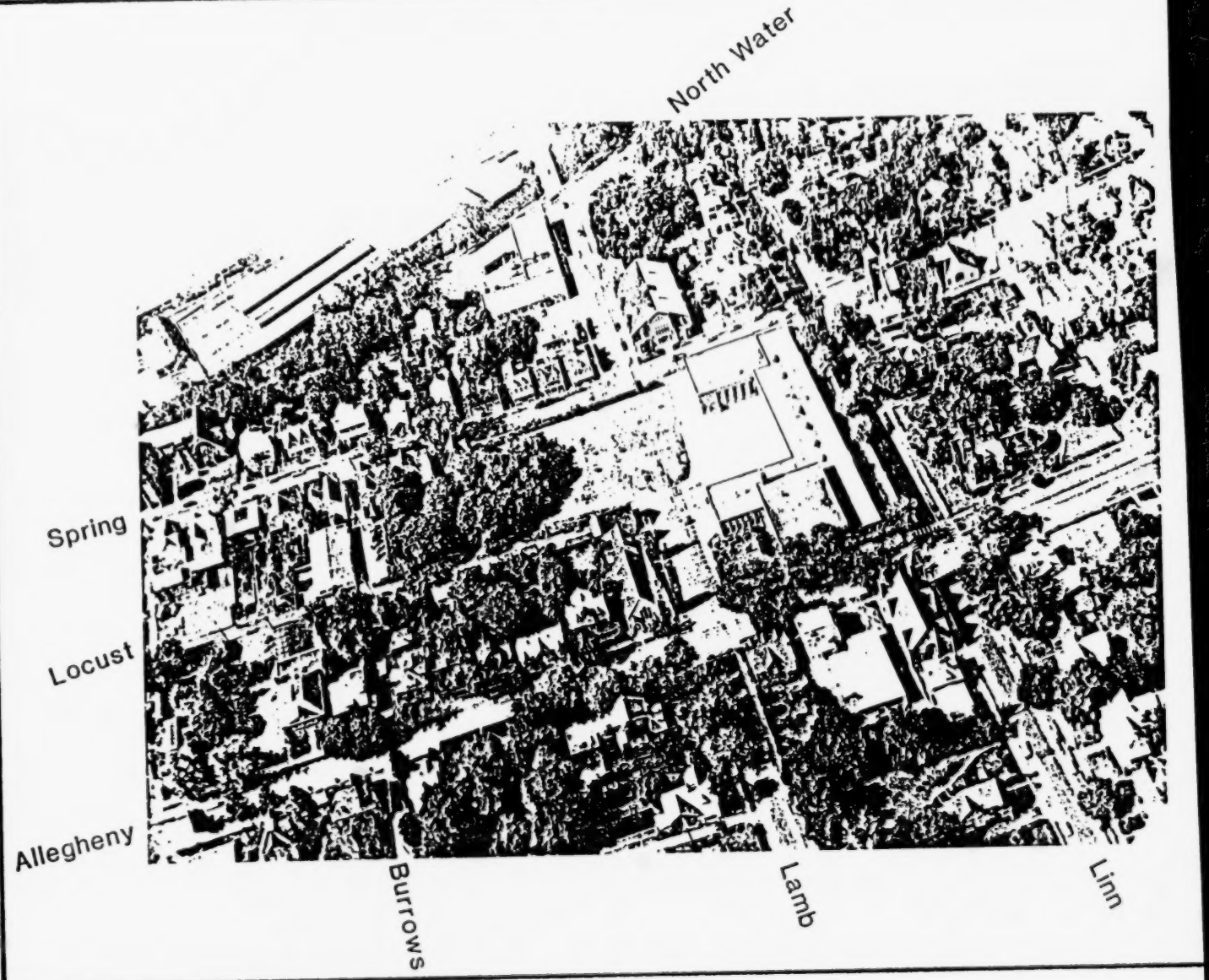


Figure 7. Aerial Photograph of School

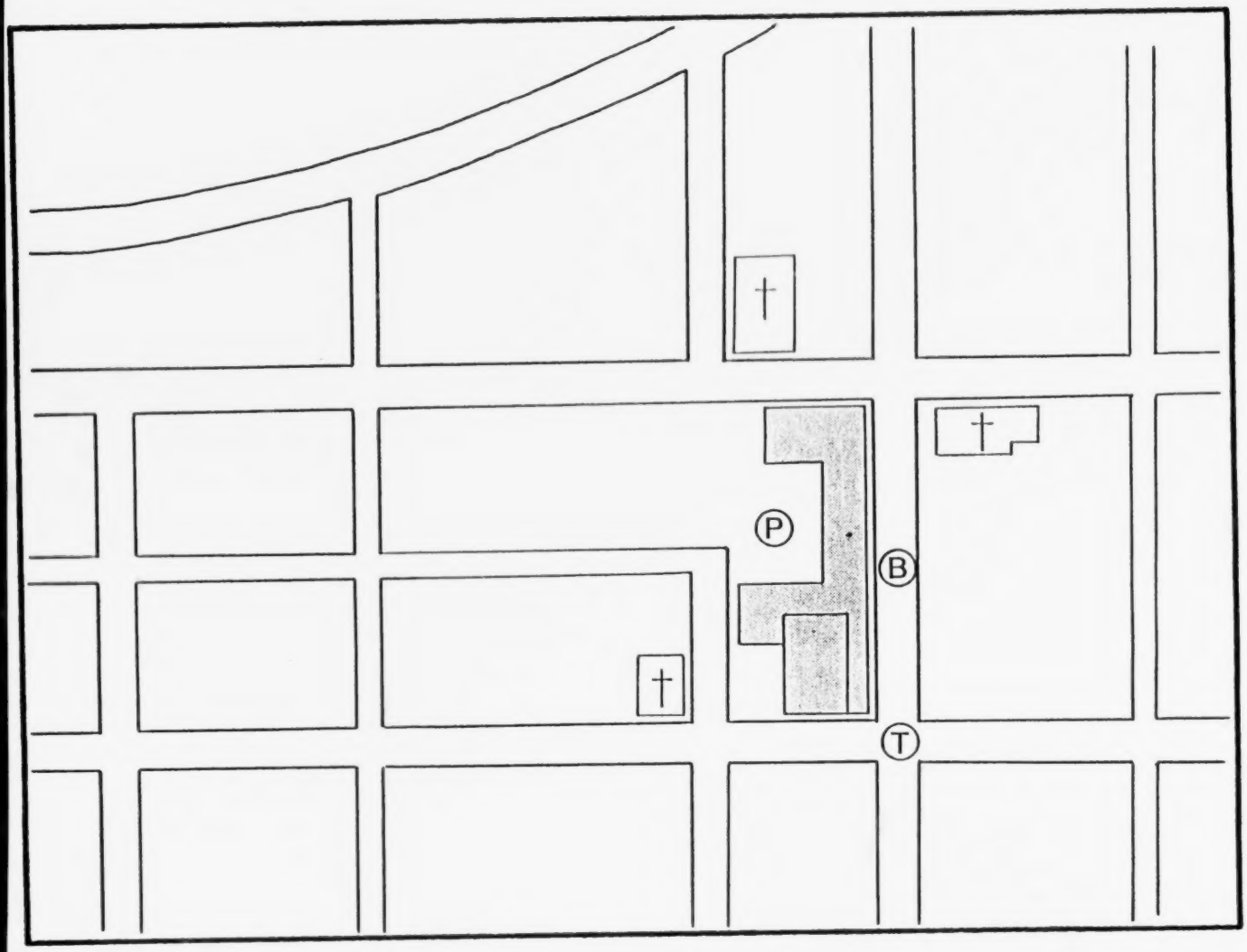
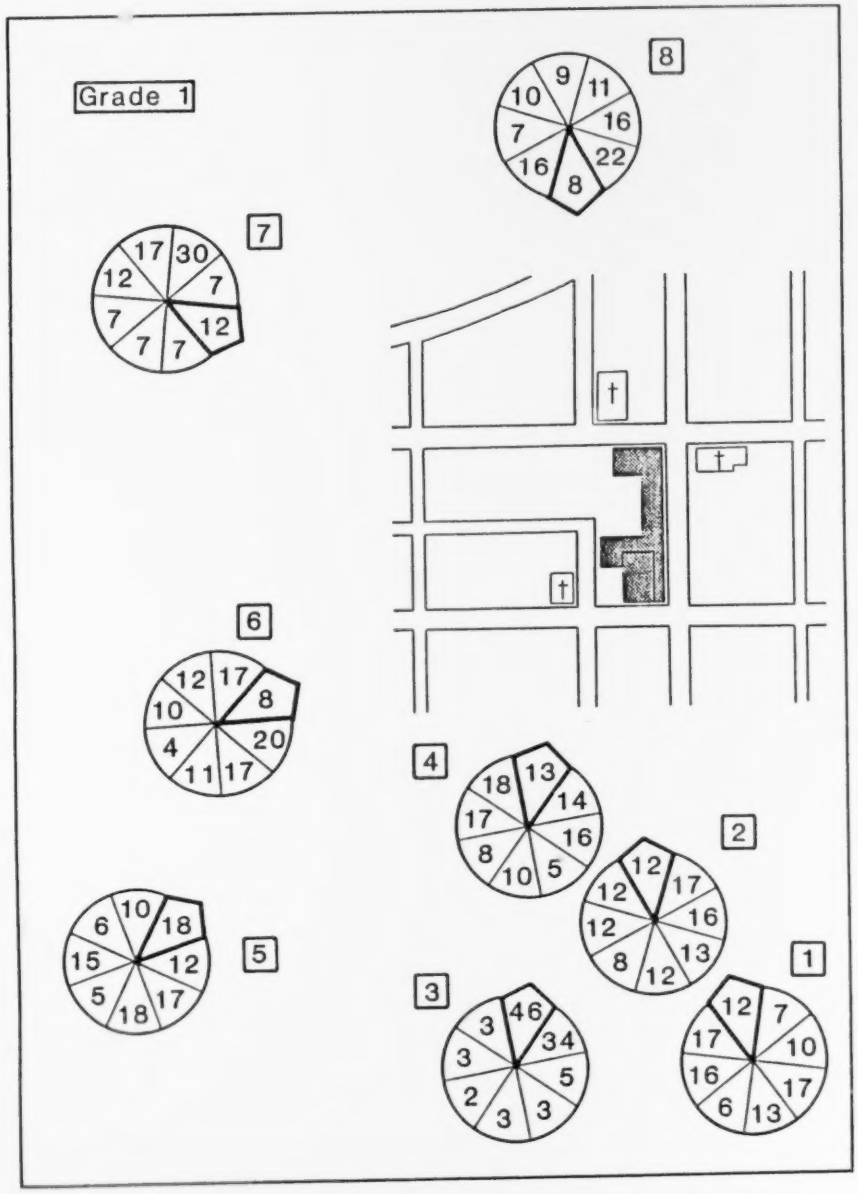


Figure 8. School Map used for Aerial Direction Task



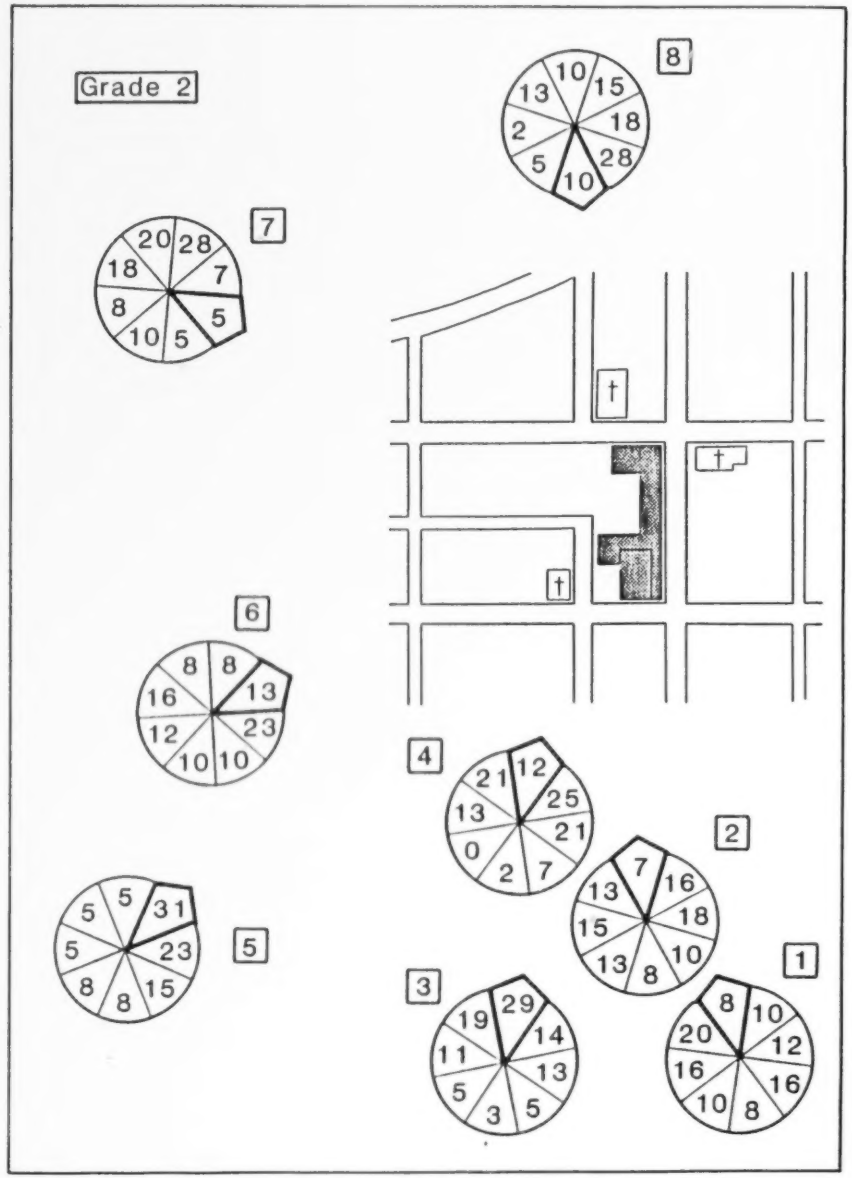


Figure 9. Aerial Photograph Directions, Percentage Distribution of Angular Responses, 45°-Segments, Grades 1 and 2

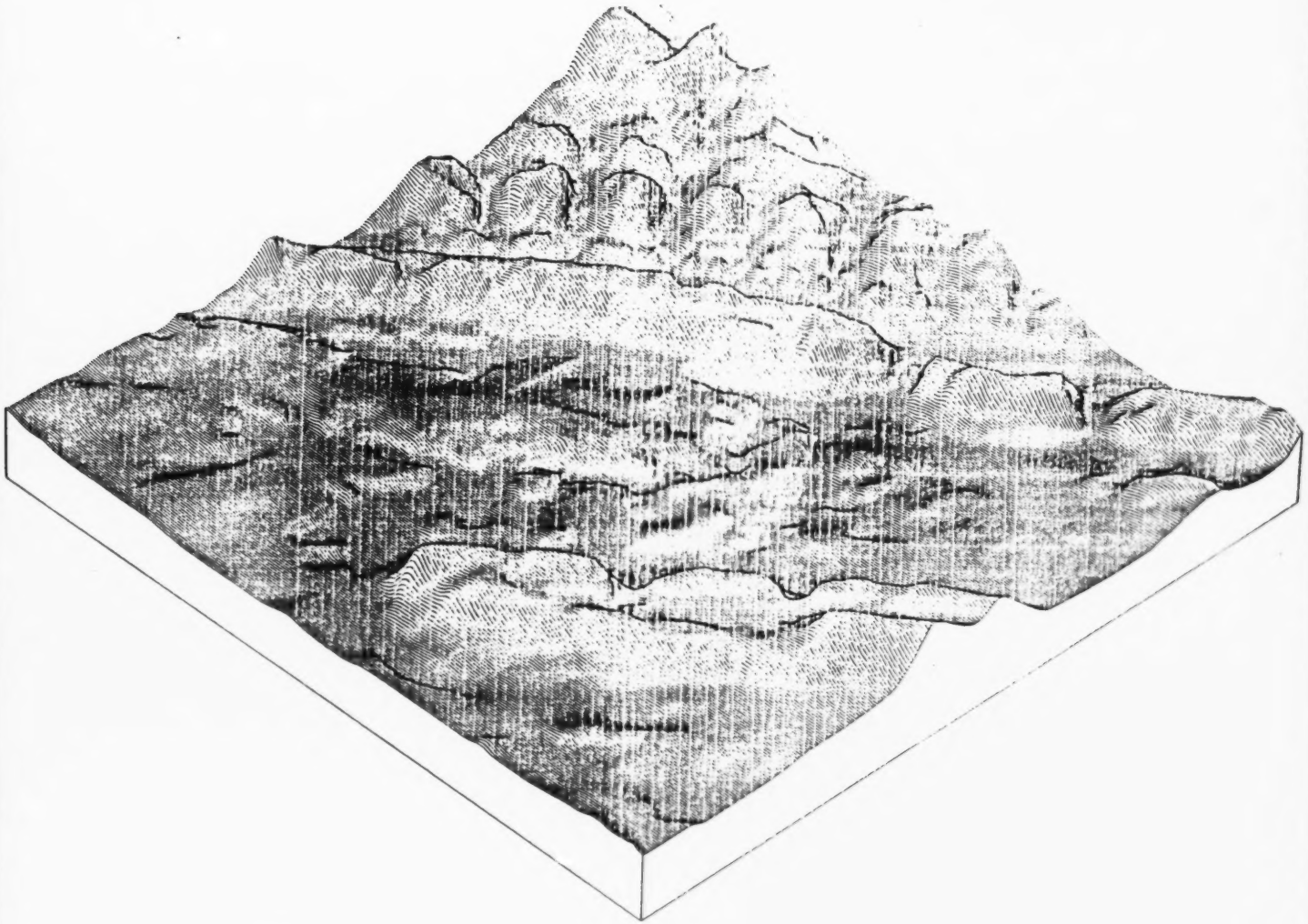


Figure 10. Sample Computer Representation of Local Region (30° Viewing Angle, 135° Azimuth)

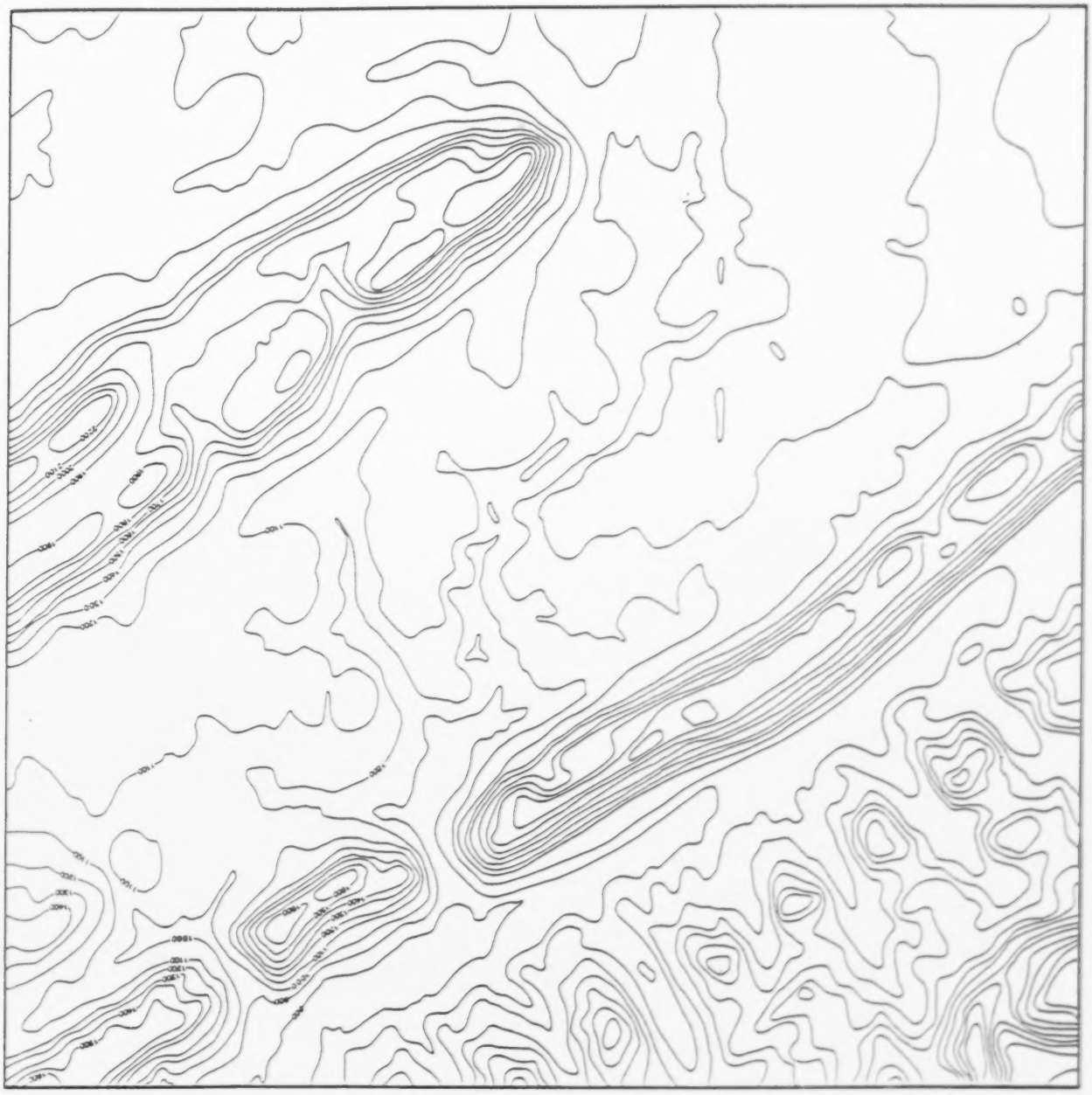


Figure 11. Contour Map of Local Region

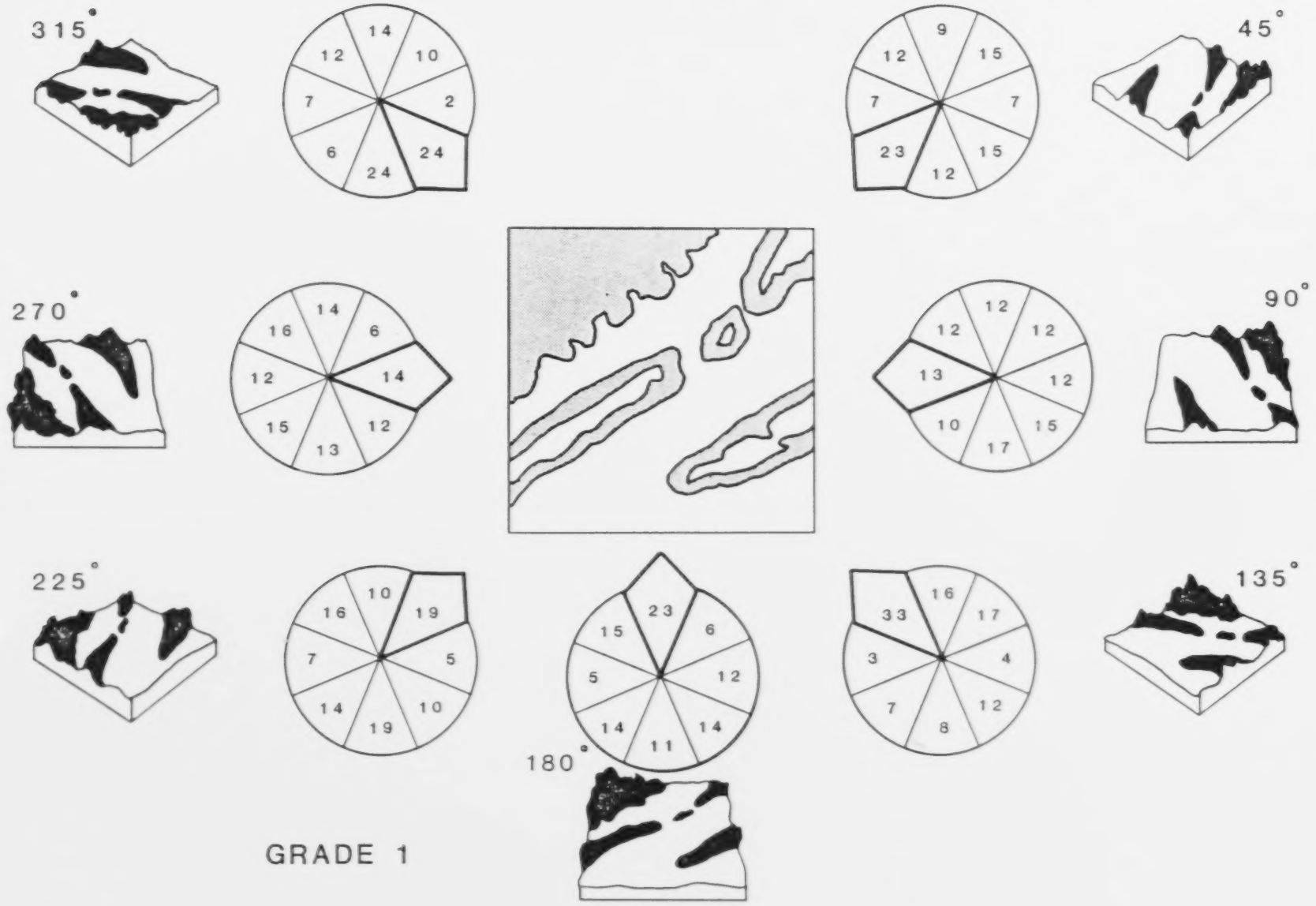
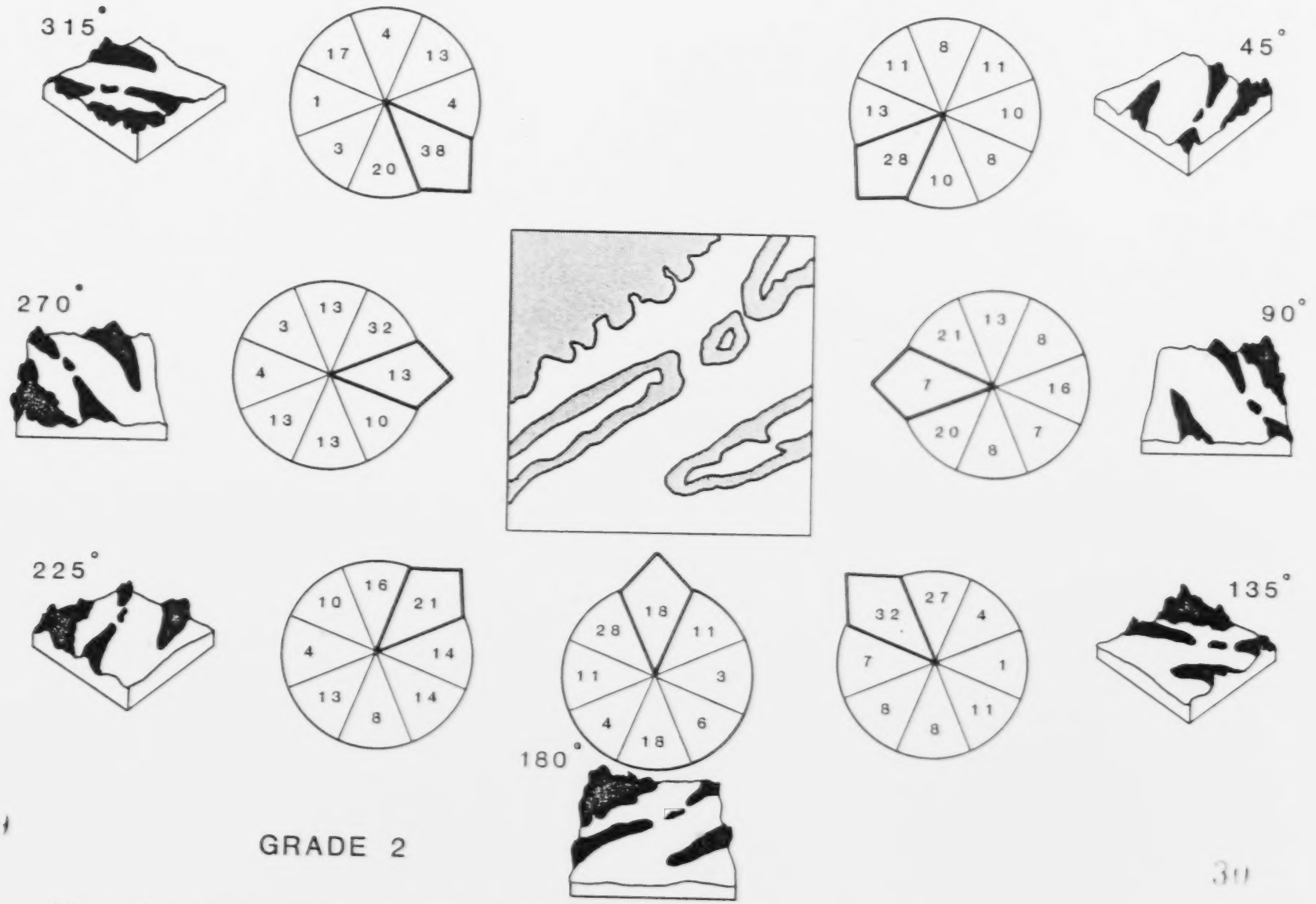


Figure 12. Computer Representations, Percentage Distributions of Angular Responses by View, Grade 1



GRADE 2

Figure 13. Computer Representations, Percentage Distributions of Angular Responses by View, Grade 2